CLAIMS

20. Stirrup for reinforcing load bearing elements having main reinforcement rods, which stirrup comprises a plurality of consecutive windings **(7a, 7b)** disposed along the longitudinal direction of the stirrup and has a continuous cross-section, so that the stirrup has a spiral form, whereby the windings of the stirrup form a plurality of discrete cages **(5a, 5b)** for housing the main reinforcement rods (**1a, 1b**) of the load bearing element.

21. Stirrup **according to claim 20,** whereby the stirrup comprises n almost cylindrically-shaped cages, where n is an integer greater or equal to 2, and whereby the projections of each n-th winding provided along a portion at least of the length of the stirrup, on a transverse plane coincide.

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22. Stirrup **according to claim 20,** whereby the stirrup comprises two cages to house the main reinforcement rods of the load bearing element.

23. Stirrup **according to claim 20,** whereby the stirrup comprises at least four cages (**5a, 5b, 5c, 5d**) to house the main reinforcement rods of the load bearing element.

24. Stirrup **according to claim 20,** whereby the shape of the windings on a transverse plane is orthogonal and adjacent windings are so disposed, that the long dimension of each winding is normal to the long dimension of its adjacent windings, so that the projection of the stirrup on the transverse plane is T like.

25. Stirrup **according to claim 20**, whereby the stirrup comprises a plurality of cages and whereby one of the said plurality of cages houses the other of the ~~set~~ plurality of cages.

26. Stirrup **according to claim 20**, whereby the stirrup is made of a continuous extruded steel rod.

27. Stirrup **according to claim 20**, whereby the stirrups are made from composite material.

28. Stirrup **according to claim 20**, whereby the windings are disposed on substantially transverse planes and consecutive windings are joined by substantially longitudinal elements.

29. Stirrup **according to claim 20**, whereby the distance between consecutive windings is uniform.

30. Stirrup **according to claim 20**, whereby the distance between consecutive windings is variable.

31. A prefabricated load bearing element comprising a stirrup **in accordance with any of the claims 20 to 30**.

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32. Method of reinforcing of shear wall elements using at least two of the stirrups of **any of the claims 20 to 30.**

33. Method of reinforcing a load bearing element comprising at least two sets of reinforcement rod elements, whereby the method includes the step of providing a spiral shaped stirrup with a continuous cross-section and a plurality of consecutive windings, which windings form a plurality of cages **(5a, 5b)**, with each cage **(5a, 5b)** tightening a different set of reinforcement rod elements.

34. A load bearing element comprising at least two sets of reinforcement rod elements and a spiral shaped stirrup with a continuous cross-section and a plurality of consecutive windings, which windings form a plurality of cages **(5a, 5b)**, with each cage **(5a, 5b)** tightening a different set of principal rod elements.

Antiseismic spiral stirrups for reinforcement of load bearing structural elements

The present invention refers to stirrups for reinforcement of load bearing structural elements, and in particular for reinforcing concrete load bearing building elements, such as columns, shear walls, beams, slabs, footings, lintels, piles. The invention refers also to a method for reinforcing structural elements as well as to these elements.

Stirrups and ties constitute one of the most critical factors of quality and antiseismic strength of buildings. Essential factors for the liability of stirrups are the proper hooks at their ends and the bend diameter at corners. The hooks at the end of the conventional stirrups are absolutely necessary for ensuring the proper functioning of the stirrup or tie in case of a very strong earthquake, when the spalling of the concrete occurs and when the hooks is the only remaining anchorage mechanism.

The following stirrups are used in building industry today:

i) Individual stirrups **8**, which may be of various forms, such as described in **figure 1**. For individual stirrups it is essential to be fastened in a plurality of points to the principal reinforcement rods **1** of the reinforcement as well as to the woodform. Thus their assembly is complicated and has a high cost. The individual stirrups **8** comprise hooks **6**, for anchoring the stirrups to the load-bearing element of the structure.

ii) "Mantles", i.e. stirrup cages made of prefabricate welded meshes (**see figure 2**). These are made of standardised welded meshes in suitable machines. The partial replacement of common stirrups by the "mantles" or "stirrup cages" was the first attempt to transform the painful task of reinforcing the load bearing elements of the structure into an industrial process. However the manufacture of the mantles is done in two phases, and only part of the process may become an industrial one: The first phase is an industrial

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process aiming in the production of plane meshes, such as shown in **figure 3**, from steel rolls using huge machines. During the second phase the meshes are almost manually assembled to form stirrup cages. The production of 'mantles" have the following limitations: a) it is difficult to manufacture compound stirrup shapes by analysing them in simple rectangular shapes, b) it is impossible to increase or decrease the spacing of the stirrups resulting in superfluous weight of the reinforcement, c) it is expensive to transport them due to the size of the cages, d) it is difficult to manufacture double hooks, which is a necessity in antiseismic structures, and e) there is a danger of buckling of the vertical binding bars in case of an earthquake.

iii) Circular or orthogonal spiral stirrups: Numerous experiments have been executed with circular spirals, which proved that if the spacing of the windings, i.e. the pitch, is kept below a minimum distance, the spirals are actually functioning like steel closed mantles, whose strength is increased due to the presence of triaxial stress system. The spiral stirrups currently known are appropriate only for reinforcing columns with rectangular cross-section. Further they are uneconomical because of the constant spacing between windings, which is determined by the shear level at the most critical region of the member. They also present problems in manufacturing and difficulties in placing them by the skilled workmen, because of the excessive weight in cases of strongly reinforced columns with many sides. Examples of sprial stirrups may be seen in EP-A-0 152 397, which discloses a stirrup for reinforcing load bearing elements consisting of a plurality of consecutive windings disposed along the longitudinal direction of the stirrup, so that the stirrup has a spiral form (see for example figure 1 of this document). Further spiral stirrups are known from AU 58 674/69 and DE-A-26 46 272.

An object of the present invention is a stirrup overcoming the problems of the known stirrups. A further object of the invention is a stirrup which may be used for reinforcing load bearing elements of various cross-sections such as columns, shear walls, beams, slabs, footings, lintels, piles.

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An object of the invention is also a method for reinforcing the load bearing elements of a structure as well as such an element.

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A stirrup for reinforcing load bearing elements according to the invention consists of a plurality of consecutive windings disposed along the longitudinal direction of the stirrup, so that the stirrup has a spiral form, whereby the windings of the stirrup form a plurality of discrete cages to house the main reinforcement bars of the load bearing element.

In accordance with a method of the invention for reinforcing a load bearing element, the principle bar elements of the reinforcement are housed within the windings of a spiral shaped stirrup whereby the stirrup comprises a plurality of cages, with each cage tightening a different set of principal bar elements.

A load bearing element according to the invention, comprises principle bar elements housed within the windings of a spiral shaped stirrup, whereby the stirrup comprises a plurality of cages, with each cage tightening a different set of principal bar elements.

Stirrups in accordance with the invention have a spiral form, so that the axial load carried by the stirrup may continuously transmitted with no interruption along its length. The windings of the stirrups of the invention form more than one cages for the principal reinforcement rods, so that they may be used for the reinforcement of load bearing elements of various cross sections such as orthogonal, T-shaped, L-shaped, Z-shaped etc. The stirrup may be brought in site compressed, and stretched during its positioning around the principle reinforcement rods. Its attachment to the reinforcement rods requires a relatively low number of fastenings – it is enough to fasten each winding to four or even three principle reinforcement rods - and involves relatively a low cost. The use of the stirrups of the invention allows the manufacture of the transverse reinforcement, which is essential for antiseismic and other reasons, to become an industrial process with low manufacturing cost and high quality of the product.

Stirrups according to the invention may be manufactured from a steel grade with very high strength, for example S1200 (1200MPa), because there is no

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need to use hooks for anchoring, which are usually the weak points of the known stirrups. A further advantage of the stirrups of the invention is that their production and the stirrups themselves, may be standardised so that they may be of high quality and they could be used for reinforcing standard types of load bearing elements.

The further features of the invention described in the dependent claims offer other advantages.

According to claim 2, the windings of the stirrup are periodically arranged, so that each cage is formed by every n-th winding where n is the number of cages.

The stirrup of claim 3 has exactly two cages. With such an arrangement it is possible to cover the reinforcements of a large number of load bearing elements.

The stirrup of claim 4 has at least four cages. Such a stirrup is adequate for load bearing elements having a relatively large number of principal reinforcement rods and/or relatively complicated cross-section.

Preferable shape of stirrups are defined in claims 5, 6, 7. According to claim 5 the stirrup has a cross section similar to the cross section of a load bearing element having at least on web and at least one flange. Such a cross section may be T, Z, double T or other.

Claims 8, 9 define preferable materials to be used for the production of the stirrups of the invention.

The preferable advancement of the windings in the longitudinal direction according to claim 10 renders the stirrup advantageous in the case of relatively high shear loads.

Claim 11 defines that the distance between consecutive windings is uniform, while according to claim 12 the pitch may vary. Thus more economically effective solutions are possible.

Claims 13 to 15 define stirrups according to the invention comprising two spiral elements.

Claim 16 defines a prefabricated load bearing element comprising a stirrup according to the invention, and claim 17 defines a method to use the stirrups for the reinforcement of walls.

The invention will now be described by way of examples and with reference to the accompanying drawings in which:

Figures 1, 2, 2a present the known stirrups.

Figure 3 shows a stirrup according to the invention fastened to the principal reinforcement rods of a column and **figures 3a** shows schematically this stirrup.

Figures 4a, 4b, 4c, 4d, 4e show schematically stirrups according to the invention for the reinforcement of columns.

Figures 5, 5a, 5b, 5c, 6, 6a, 6b, 6c, 6d, 6e and 7, 7a present spiral stirrups having L, T and cross-shaped cross-sections respectively

Figures 8, 8a, 9 present spiral stirrups, adequate for footings or beams.

Figures 10, 10a present a spiral stirrup, adequate for a load-bearing wall.

Figures 11a, 11b, 11c, 11d, 11e, 11f show stirrups according to the invention for the reinforcement of load bearing elements having a Z-shaped cross section.

Figures 12 present a spiral stirrup with variable pitch.

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Figure 13 shows a stirrup according to the invention consisting of two spiral elemets shown in **figures 13a and 13b**.

Figures 14a, 15a, 16a, 17a present a method of reinforcing load-bearing elements in accordance to the invention applied to the elements shown **in figures 14, 15, 16, and 17.**

Referring to the attached drawings we shall describe some indicative examples of the antiseismic spirals according to the invention. These are spiral stirrups usually manufactured by robot machines, from coiled rods of Φ4 to Φ16 in steel rolls of every quality and grade. The use of the coiled rods provides the possibility to produce the stirrup in the shape of a spiral with no discontinuation, in one piece of compound shape. They are manufactured compressed and they are stretched with relative convenience during their placing. Stirrups according to the invention may be also made of composite materials, for example from glass fibres.

Figure 3 shows a stirrup according to the invention. The spiral stirrup of this figure has consecutive alternating windings **7a** and **7b**. The set of windings **7a** forms a cage **5a** to house the principal rods **1a** of the reinforcement. In use the windings **7a** are tightened around the rods **1a** and it could be enough to fasten each winding even to three rods. Similarly the set of windings **7b** form a cage **5b** to house the principal rods **1b** of the reinforcement. Thus the stirrup includes two cages **5a, 5b**, whereby each one of the cages **5a, 5b** is formed by the alternating windings **7a, 7b** respectively. The projections of windings **7a** on a transverse plane coincide, so that the cage **5a** is cylindrical or approximately cylindrical. Similarly cage **5b** is cylindrical or approximately cylindrical, as the projection of the windings **7b** on a transverse plane coincide. In the case of the stirrup of **figure 4** the pitch is constant along the length of the stirrup, so that not only the projections of windings **7a** coincide, but also the spatial shape of these windings is identical. The same applies for windings **7b**.

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Figure 3a shows schematically a cross sectional view of the stirrup shown in **figure 3**, whereas **figures 4a, 4b, 4c, 4d, 4e** show cross sectional views of other stirrups to be used for the reinforcement of columns. The stirrup of **figure 4a** has two cages **5a, 5b** with overlapping cross sections, and **figure 4b** shows a stirrup with an almost rectangular cage **5b** within a polygonal cage **5a**. Such a stirrup may be formed with a circular or elliptical outer cage. Further stirrups for columns with rectangular cross-sections are shown in **figures 4c, 4d and 4e**.

Figures 5, 5a, 5b, 5c present spiral stirrups having L-shaped cross-sections comprising two (**see figure 5a**), three (**see figure 5b**) or four (**see figure 5c,** cages **5a, 5b, 5c, 5d**) cages. **Figures 6, 6a, 6b, 6c, 6d, 6e** present spiral stirrups with T-shaped cross sections, and **figures 7, 7a** a stirrup with a cross-head cross-section. T-shaped spiral stirrups, which are also used for the reinforcement of footings, have an excellent performance when they carry simultaneously shear, torsional and flexural loads.

Figure 8, 8a show a spiral stirrup to be used for the reinforcement of a beam or footing, with two overlapping cages **5a, 5b**, according the invention. With this arrangement a single spiral may be used for each footing or beam. **Figure 9** shows a spiral stirrup with three cages **5a, 5b, 5c** to be used for the reinforcement of a beam of a bridge.

Figure 10 shows the axonometric representation and plan view of a concrete shear wall with a spiral stirrup shown schematically in **figure 10a**.

Figures 11a, 11b, 11c, 11d, 11e, 11f show indicative representation of spirals for Z-shaped columns, which are often used at the corners of buildings.

With suitable programming of the production machine of the stirrup or appropriate fastening of the legs of the stirrup with the principal reinforcement rods, advancement of the windings along the length of the stirrup may be effected through longitudinal elements, while the windings remain at a

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substantial transverse plane. Such an option allows the use of the spirals in beam elements and footings that carry relatively high shear forces.

The pitch of the windings may be uniform or variable, as shown in **figure 12**. The variation in pitch may be effected either during production or during the reinforcing of the load-bearing element. With this arrangement the optimum economical solution arises because the variation of the pitch of the spiral may follow the shear forces diagram. **Figure 12** shows the spiral stirrup of **figure 3**, divided in parts with constant pitch. For example for a distance of 0,5 m in the base and 0,5 m in the top of the member the pitch equals to 10cm and 12 cm respectively, whereas along the middle portion of the stirrup, which extends along a length of 2 meters, the pitch is 20 cm. This arrangement results in a highly efficient solution, since it strengthens the "critical regions" of the load-bearing element with shorter winding spacing. The stirrup of **figure 12** may be used for the reinforcement of a column, beam or other structural elements.

The stirrup of the invention may be manufactured by a continuous extruded steel rod or by parts. With this arrangement the spiral is constructed by a number of spiral elements manufactured individually. The spiral elements may be constructed by rod with the same or different cross-section and may have the same or different pitch. In order to form the stirrup the spiral elements are placed side by side along their longitudinal direction and their ends are joint, so that one spiral element extends on one side of the joint and the other on the other side thereof. The joints may be effected in various ways: For example the two ends to be joint may be provided with hooks having an angle >= 135°, and one spiral element may be fastened to the other through these hooks. Alternatively each end of the spiral elements is provided with a winding having a very small or even zero pitch which are welded together to effect the joint. Joint of the spiral elements may be also effected by the combination of the two previous arrangements. **Figure 13** shows a stirrup made of the two spiral elements **3', 3''**, shown schematically in **figures 13a, 13b**, which is to be used for the reinforcement of beams, columns or other structural elements.

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The joint of spiral elements to produce a spiral with the features of the invention may be effected in site or it may be prefabricated

Figures 14a, 15a, 16a, 17a show the application of spiral stirrups in accordance with the invention, for the reinforcement of the shear wall elements shown in **figures 14, 15, 16, and 17** respectively. The walls may be of large sizes and in general they may have a rectangular, angular, lift type etc. cross sections. In accordance with the method the combination of regular size spiral stirrups with longitudinal rods **4**, which may have hooks **6'** - 90° or 135° or other angle – at their ends effects the reinforcement of the walls. Other ways of attachment of the rods to the stirrups are also possible. Spiral stirrups are placed at shear walls ends and they tied or welded to the longitudinal rods, which in the case of te examples shown in the figures, are normal or almost normal to the longitudinal direction of the stirrups. Although particular advantages are offered by this method of reinforcing when applied in combination with the spiral stirrups of the invention, other spiral stirrups may be also used.

The stirrups of the invention may be used for the reinforcemnet of prefabricated load bearing structural elements.

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